Low temperature combustion (LTC) concept has evolved over last two decades in response to demand for lowering NOx and soot emissions from direct injection (DI) diesel engines. LTC delivers improved thermal efficiency of gasoline-fuelled engines and ultra-low NOx and soot emissions of diesel-fuelled engines, which makes it a strong potential alternative technology to existing combustion technologies. Although remarkable progress has been made in LTC technology, large-scale production of LTC engines for commercial application still remains challenging and is infested with several operational difficulties. Limited operating range, lack of direct control on SoC, difficulties in obtaining homogeneous fuel-air mixture preparation and higher HC and CO emissions are the main hurdles for LTC technology adaptation in production engines and vehicles for commercial applications. Several techniques have been developed for low-load applications of LTC technology in heavy-duty engines, however full-load applications, even in light-duty engines have not been experimentally demonstrated until now. Fuel flexibility is another important feature of LTC. Fuel properties significantly affect chemical kinetics, which has a dominating role in LTC. Based on engine design, operating conditions and control strategies employed, different fuels such as biodiesel, alcohols, kerosene, etc. have been demonstrated for LTC applications with partial success.

In LTC, auto-ignition can be controlled by modifications of fuel properties with on objective to make it more chemically reactive or inhibitive by adding an ignition promoter or inhibitor, as per the requirement. Vital properties of fuel-air mixture are directly controlled by the fuel properties. Based on fuel properties, three distinct fuel-air mixture preparation techniques namely, port fuel injection; early direct injection and late direct injection can be applied to LTC engines. Different derivatives of LTC such as PCCI, PHCCI, etc. have been thoroughly investigated and suitability of each derivative was determined for a particular operating range. To explore applicability of each LTC derivative for developing a production grade LTC engine, this study was divided into three sections namely (i) partially homogeneous charge compression ignition (PHCCI) combustion, (ii) premixed charge compression ignition (PCCI) combustion and (iii) mode switching between conventional CI combustion and LTC. Mode switching involves dual combustion modes, depending on operating condition, which is an effective solution for commercializing LTC technology. In PHCCI combustion investigations, five test fuels were investigated at different loads, EGR rates and intake charge temperatures. These experiments validated feasibility of LTC using low volatility fuels such as mineral diesel. PCCI experiments were carried out to explore the possibility of different combustion modes using fuel injection strategy. After successfully achieving control over PCCI combustion, optimized fuel injection strategy was implemented on a production grade engine to achieve mode switching between conventional CI combustion and LTC. This experimental study involved a journey starting with the fundamental combustion investigations of PCCI and culminating into development of commercially viable mode switching LTC engine prototype, which will be energy efficient and environment friendly.